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REMARKS

ON THE CONSTRUCTION OF THE COMMON SCALE-BEAM, WITH A DESCRIPTION OF THE NEW GOLD STANDARD BEAM, INVENTED BY THE AUTHOR,

Mr. BENJAMIN DEARBORN.

THE common Scale-Beam has a *fixed* centre of gravity at some distance below the centre of motion ; by this construction the beam is drawn to a level or horizontal position ; the power, by which it is thus influenced, is invariable, and is proportioned to the weight of the beam and the distance of the two centres abovementioned.

DEMONSTRATION.

Fig. 1 represents the central part of a scale-beam, constructed as usual, with the centre of motion at *a*, and the centre of gravity at or near *b*, considerably below *a*. If the two arms of the beam be equal in weight, the power of gravity will draw the centre *b*, directly under the centre *a*, in the line *c d*. To turn the beam *out* of a level position, a power must be applied superior to that, which draws it *into* a level position. If the beam weigh *three* pounds, with two thirds of its weight below the centre of motion, it will require three times the quantity to turn it into any given angle with the horizon, which would be necessary, if it weighed but *one* pound, with two thirds of its weight below the centre of motion, as in the other. If the centre of gravity were raised nearer to the centre of motion, the beam would turn with less difficulty : if both centres were in one point, the beam would stand in any position, and turn with the utmost ease, but would not vibrate. If the centre of gravity were above the centre of motion, one end or the other of the beam would preponderate, as chance or accident might direct. The preceding remarks principally concern the *light* beam; I shall next speak of the *loaded* beam.

The strength of a beam must be proportioned to the quantity it is designed to draw; and if strong it must be heavy, and if heavy it must turn with difficulty, on the construction above described, if no measure be adopted as a corrective; and the only corrective I have known applied, is a much *greater* evil to correct the *smaller;* this I shall endeavor to explain. Some workmen, finding the difficulty attending the turning of a beam was nearly in proportion to the weight of the beam, have raised the points of suspension considerably above the centre of motion, whereby the beam is made to turn with ease when loaded with a *certain weight*, but loaded beyond this quantity it becomes what is vulgarly termed a *dead beam;* that is, one scale or the other will preponderate and remain down; while the same beam, if lightly loaded, will turn with difficulty. In either of which extremes accuracy is not to be expected, the beam being fit for weighing *only* that intermediate quantity, with which it will vibrate when equally balanced, and will turn with ease.

Demonstration of the cause, which produces the effect above mentioned.

IN the line *a b c* Fig. 7, let the point *b* be the centre of motion; *d* and *e* are the points of suspension, (which are here raised to an extreme, to make the explanation more intelligible.) It is evident that the points of suspension vibrate in arcs of the circle *a d g e c*, of which *b* is the centre; that while the beam is level, the points *d* and *e* are at equal horizontal distances from the centre, and that those distances are equal to the co-sine of the angle *e b c* or the line *b f;* depress the point *e* to *c*, and the point *d* is raised to *g;* the horizontal distance of the former being increased to the radius, and that of the latter reduced to the co-sine of the angle *g b a;* hence the falling arm of the beam obtains the power of a longer lever, while the power of that, which rises, is at the same moment reduced in a greater proportion. As this inequality of power increases by multiplying the weights in the scales, it follows that the beam operates very differently when lightly or heavily loaded, and that it can be correct *only* when the scales are loaded with that precise quantity, which shall give a power to the longer lever but just inferior to the power of gravity, which draws the beam to a level. It is further evident by Fig. 8, that if the points of suspension were placed below the centre of motion, the evil would be still greater, as the rising arm would increase in power, while the other would be losing; in this state a beam turns with the greatest difficulty; it therefore follows that the points of suspension should be placed on a line with the centre of motion, or not so far out of that line as that the beam will operate differently with different weights. Yet even in this construction a *natural evil* arises, which cooperates with the first of the before mentioned *artificial* evils to obstruct the easy motion of a beam; this I shall next attempt to describe.

The *natural evil,* above alluded to, is the flexion or bending of the beam when considerably loaded, whereby the points of suspension are drawn downward below the centre of motion; this operates powerfully against the turning of the beam, and unites its effect with the fixed centre of gravity, to prevent an easy motion; hence arises the principal cause of the difficulty, with which a beam turns when heavily loaded; not from the friction of the parts alone, as is commonly, though erroneously, supposed.

Demonstration of the above position.

IN the line *m n o,* Fig. 8, *n* is the centre of motion, *p* and *q* are the points of suspension, depressed below the horizontal line. As the points vibrate in the arcs *r s* and *t u*, the rising arm becomes the increasing lever, while it moves from *q* to *o*, and the falling arm in the same period, passing from *p* to *r*, is in more rapid progression losing its power. Fig. 8, which is the reverse of Fig. 7, demonstrates, that reversing the cause reverses the effect, as the falling arm is gaining power in the first instance, and the rising arm in this; yet in both, the increase of power is proportioned to the increase of weight, therefore the more a beam is loaded, the greater is *this* obstacle to its turning, and with the greater force *it is drawn to a level by its own flexion.*

As no inflexible or nonelastic substances exist, the maker of scale beams must ever have to encounter the inconveniences, arising from the flexion of the bar, which I have termed a natural evil, as it cannot be avoided. It may be *successfully* counteracted in the construction of a beam; but not by the method usually adopted, which is to make the beam so strong as to be scarcely susceptible of flexion, with any weight it is designed to draw: it is consequently heavy, as before remarked, with a heavy centre of gravity drawing it to a level; of course the power, necessary for turning it to any given angle with the horizon, must bear a proportion to the quantity of matter in the beam.

The justice of the above remark is particularly exemplified in the beam, which has lately been imported from London for the use of the Union Bank in Boston. The beam alone weighs nearly thirty pounds avoirdupoise, and appears sufficiently strong for bearing, without injury, at least ten times the quantity, for which it was ordered; the centre of gravity is placed as usual; and although it turns as easy as a beam of that size and construction can, yet five penny weights being placed on one of the hooks, designed for the scales to hang upon, gave the index less motion, (notwithstanding the beam was not loaded) than five *grains* at the same time gave to the index of my beam, while each of the scales was loaded with six thousand pennyweights. This experiment was witnessed by the cashier and some other gentlemen. One other inconvenience attending the common scale beam arises from the lateral vibrations, to which it is subjected, by being suspended from above, as all swinging motions tend to interrupt the regular oscillations of the beam upon its centre; but this I do not consider as an object of magnitude; yet it is of sufficient importance to be avoided, when it may, especially where minute accuracy is required, as in sealing weights, &c.*

I shall now attempt an explanation of the means, devised in the construction of my Gold Standard Balance, for correcting or avoiding the evils beforementioned. See Fig. 9.

The largest size, required in Banks, is calculated for sustaining a weight in each scale, equal to a quantity of gold amounting to five thousand dollars, or between nineteen and twenty pounds avoirdupoise. The beam for this purpose is twenty five inches long, and weighs about three pounds; the base, which supports it, is a mahogany box or board, ten inches wide and fourteen long, with a screw in each corner for adjusting it in a level position. Four columns rise sufficiently high from the base for giving convenient length to the chains or cords of the scales; two of these stand contiguous, near each side, leaving in the centre a space of six inches for the motion of the index, which extends downward from the beam. In this space a lever is fixed for raising the beam with the scales and their load. One end of this lever is raised, and supported when up, by a bended lever and friction-wheel, the weight of the beam &c. pressing on the centre of the first mentioned lever. The pedestals and capitals of the columns are conformable to the Tuscan order of architecture, and on the top of each pair is a brass plate screwed down by rods, passing through the columns to the lower surface of the base. From one of these plates to the other two semicircular brass arches extend across, with a proper distance between them for the beam. On the internal surface of each of these arches a perpendicular dove-tail groove is made, to guide the top of the parallel, by which the beam is supported. This parallel consists of two similar parts, each of which is formed by two rods of iron, united at top and bottom, opening in the centre, and extending from the arches nearly to the base. A piece of steel is welded on the upper extremity, which is hollowed into an arch of a large circle, well tempered and polished; the lower end of each part is riveted into an iron plate, at a distance apart equal to the distance of the brass arches above; in the centre of this plate a pin is screwed, extending downward to the lever, on which it rests; a guide, through which this pin passes, and the grooves above regulate the perpendicular movement of the parallel, and prevent any lateral motion. The axis of the beam rests in the hollow at the top of the parallel, and its sharp edge is the only part, which comes in contact with other parts, when the beam is in use. This is effected by perpendicular and inclined planes in each key-stone of the brass arches, whereby the axis of the beam is so governed, that it can rise only in its assigned position, preserving the central situation of the beam between the sides of the parallel, and preventing it from touching either.

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* It is probable that from the *want* of this minute accuracy, arises that inequality of Standard Weights, which will discover itself to any one, who shall take the trouble to make a comparative experiment. From the instances, in which I have compared, a doubt has arisen in my mind, whether there are two sets of weights on the continent, exactly agreeing with each other, and in which the component parts correspond with the whole.

The principal peculiarity of the beam, consists in the manner of forming and finishing the ends for suspending the scales. It resembles the common swan-neck beam reversed; the extremities, which are of steel, are wrought to a sharp edge, turning upward, exactly on a line with the edge of the axis or centre of motion, and equidistant from it. To obtain exact equality in the distances the ends, after being tempered, are made sharp by rubbing with an oil-stone, whereby the length of either arm can be increased or diminished in the smallest quantity required. For attaching scales to the beam, two implements, termed pendants, are suspended on these sharp edges; they are thus formed. Between two parallel brass plates, about three inches long, are inserted, at the upper end a steel cap, well tempered and polished, and at the lower end, an iron plate, with a hole in the centre. Through this hole an eye-bolt is passed upward, and a double nut is screwed on above the plate. By this construction the suspension of the scales is so adjusted, that when let down, both will rest on the table at the same instant, if the beam be level. The pendants thus constructed, produce the least possible friction, as thieir sides can touch the beam in no part, except a single point at each extremity of the sharp edges, which are much longer than the thickness of the beam. Over the centre of the beam a small weight, in the form of an antique vase, turns on an axis toward the right or left, and is adjusted by two screws; this is termed an Equipoise, its design being to level the beam, when either end may have obtained a preponderance from unequal wearing of the scales, magnetic attraction* or other causes, some of which may be inexplicable, as experience demonstrates that a beam, turning very easily, and accurately adjusted, will in time lose its balance. The index, which is an iron rod about eighteen inches long, and made truly cylindrical, is screwed into the lower edge of the beam, and well braced. Just below the extremity or point of the index, a pallet moves upon an axis, in such a manner, that when one end is pressed down, the other rises against the end of the index, and stops its vibrations. On this pallet a centre-line is marked, for determining the exact level of the beam; and when the parts are thus far completed, the centre of gravity must be considerably above the centre of motion. An instrument, termed a Motor*, is made to slide on the index, having a spring to keep it at any point assigned; the form of the motor may be such as the fancy suggests, but its weight must be just sufficient to depress the centre of gravity a little below the centre of motion, when placed near the lower end of the index. Its proper place may be known by first raising it so high that the beam will not vibrate, then move it lower by degrees, until the beam vibrates with a slow motion. In this state a single grain will turn the beam, if lightly loaded. When a large weight is to be ascertained, and extreme precision is required, the motor should be raised, until the beam will just vibrate with the scales charged. Whether the beam be light or loaded, it will become dead, if the motor be too high; that is to say, one arm or the other will prepon-

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* Having noticed beams, which in time had lost their original equilibrium, the circumstance led to an inquiry into the causes of such variation, and suspecting that one of them might be found in magnetic attraction, I sought conviction in experiment. Upon approaching the north point of a magnetic needle with one

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end of a scale-beam, which had been some years in use, the attraction was powerful; on turning the other end of the beam, the needle was repelled with equal force. This power has probably great influence over the iron weights, which are used in large scales.

* The term Motor signifies " a mover," and is here adopted because the implement, to which it is applied, moves the centre of gravity, and thereby gives to the beam its state of great sensibility or promptness to motion.

derate, and remain down. When the motor is too low, the oscillations of the beam are quickened, and it does not turn with the ease, of which it is susceptible. The beneficial effects of the motor arise from this cause. While the centre of gravity is below the centre of motion, it tends to draw the beam to a level position. The flexion of the beam, by the power of the weights, has the same tendency, as exemplified in Fig. 3. Hence *two* obstacles are to be surmounted, whenever a beam is charged with weights sufficient to spring it downward. If the motor be raised, it raises the centre of gravity *above* the centre of motion, and one of those two obstacles is not only removed thereby, but is brought into a position to counteract the other obstacle. A standard is fixed under each arm of the beam to support it when at rest, and it should be let down upon those supports, whenever the place of the motor is to be changed, or the scales to be loaded or discharged. A balance of this construction turns with the ease, necessary for weighing the smallest pieces of coin singly, and is almost equally susceptible when charged with six thousand pennyweights in each scale.

A Gold Standard Balance of the foregoing description is distinguished as the *higher style.* The same principles have been applied in the construction of another of equal size and accuracy, but less expensive; this is denominated the *lower style,* as it is inferior in elegance and convenience. Another of the higher style has been made upon a reduced scale for weighing gold, not exceeding the amount of one thousand dollars at a draft.

A Silver Standard Balance has also been made, for ascertaining the exact number of dollars in any parcel, from five to one thousand. This, if deserving the notice of the Academy, may form the subject of a future communication.

Since writing the preceding remarks, an argument in favor of the common swan-neck beam has induced me to add some observations on that instrument. A hook, suspended on the internal edge of a circle, must touch one point only at the bottom of the circle, or must touch more. If it touch but one point, it has not sufficient bearing for retaining the sharp edge of the circle and the roundness of the hook, suspended on it. If it touch more points than one, its bearing must be distributed on the bottom of the circle and on parts, which are higher than tne bottom. In this case the sharp edge of the circle scrapes the sides or the bottom of the hook, to the exact extent of the angle, made by either end of the beam in its oscillations; and no piece of mechanism admits of being *scraped* into easy motion. The consequence, which results, will be readily seen, on examining beams of this construction, after being long in use; either the sharp edge of the circle is worn down, or a notch is cut in the hook, embracing the edge of the circle, and preventing the freedom of oscillation. It is therefore not uncommon to find beams in daily use, which require one hundred times the weight to turn them, that would be sufficient for a beam, properly constructed and kept in order.

If a description of an improved Hydrostatic Balance of simple construction, for gold and silver coins, would be acceptable to the Academy of Arts and Sciences, it shall be presented in a future communication.*

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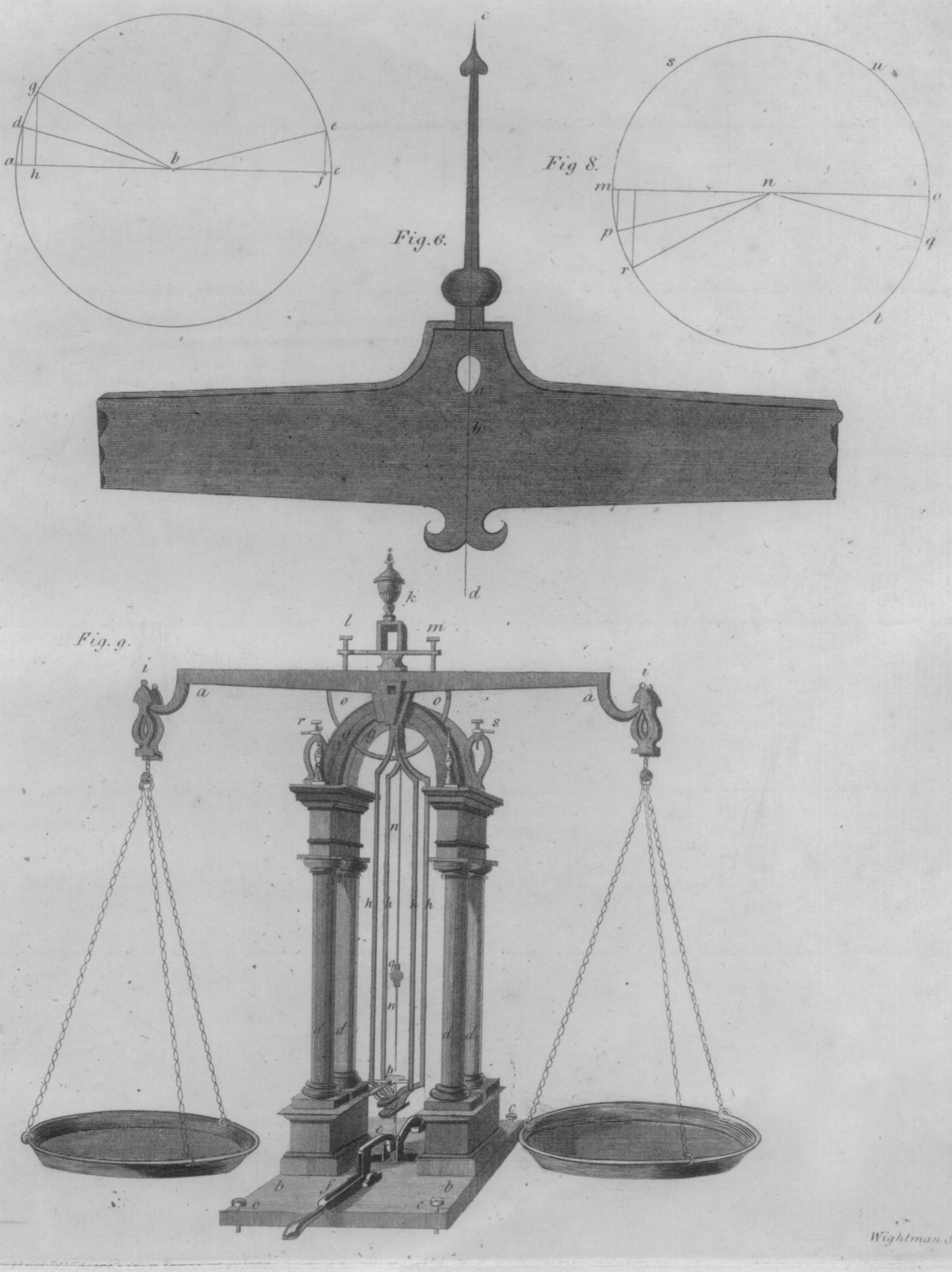
* The original communication, dated Boston, August 10, 1801, has been revised by the Author, and his late improvements in the Gold Standard Balance are described in the explanation, and represented in the plate.

REFERENCES.

a a, Fig. 9. The beam, raised to its position for use.
b b The base.
c c c Three of the four adjusting screws in the base.
d d d d The four supporting columns.
e The first lever, supporting on its centre the parallel *h h h h.*
f The second or bended lever, forked, and holding a friction-wheel to raise and support the first.
g g The two semicircular brass arches, between which the beam vibrates.
h h h h The parallel.
i i The pendants.
k The equipoise, regulated by the screws *l m.*
n n The index.
o o The brace of the index.
p The pallet.
q The motor.
r s Two supports for the beam, on which it rests, when not in use.



Penniman Del.

Wightman Sc.